VERIFICATION OF TRANSLATION

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[Title of the Invention] Self-emitting element, display panel, display apparatus, and method of manufacturing self-emitting element

[Scope of Claims for Patent]

[Claim 1] A self-emitting element comprising:

a light-emitting layer that is disposed between electrodes and that emits light upon applying a voltage between the electrodes;

a protective layer that covers an emitting side of the light-emitting layer, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once at the interface in an area of the light-emitting layer;

a reflective layer that covers an opposite side, as viewed from the light-emitting layer, of the protective layer; and

an angle changer that is disposed at a periphery of the light-emitting layer, and changes a direction of the light propagating in the protective layer so that the light is incident on the interface at less than a critical angle.

[Claim 2] The self-emitting element according to claim 1, wherein the reflective layer is one of the electrodes.

[Claim 3] The self-emitting element according to claim 1, wherein the angle changer is a reflective surface that is inclined so that a space at the emitting side increases.

[Claim 4] The self-emitting element according to claim 1, wherein the angle changer is a refractive surface that is inclined so that a space at the emitting side decreases.

[Claim 5] The self-emitting element according to claim 1, further comprising a bank that projects on the emitting side to separate the light-emitting layer from other light-emitting layer, wherein an inner surface of the bank is the angle changer, and the protective layer is formed in an area that is enclosed with the bank.

[Claim 6] The self-emitting element according to claim 1, further comprising:

a bank that projects on the emitting side to separate the light-emitting layer from other light-emitting layer; and

a protrusion, made of an insulating material, that projects toward the emitting side from the bank, wherein

an inner surface of the protrusion is the angle changer, and the protective layer is formed in an area that is enclosed with the protrusion.

[Claim 7] The self-emitting element according to claim 1, wherein the light-emitting layer is an organic electro-luminescent layer.

[Claim 8] A display panel comprising:

a plurality of light-emitting layers, each of the light-emitting layers being disposed between electrodes, and emitting light upon applying a voltage between the electrodes;

a protective layer that covers an emitting side of the light-emitting layers, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layers to undergo total reflection at least once at the interface in an area of the corresponding light-emitting layer;

a reflective layer that covers an opposite side, as viewed from the light-emitting layers, of the protective

layer; and

a plurality of angle changers, each of the angle changer being disposed at a periphery of each of the light-emitting layers, that change direction of the light propagating in the protective layer so that the light is incident on the interface at less than a critical angle.

[Claim 9] The display panel according to claim 8, further comprising a plurality of banks, each of the banks projecting on the emitting side to separate the light-emitting layers from each other, each of inner surfaces of the banks being each of the angle changers, and the protective layer being formed in an area that is enclosed with the each of the banks.

[Claim 10] The display panel according to claim 8, further comprising:

a plurality of banks, each of the banks projecting on the emitting side to separate the light-emitting layers from each other, and

a plurality of protrusions, each of the protrusions, made of an insulating material, projecting toward the emitting side from the each of the banks, wherein

each of inner surfaces of the protrusions is each of the angle changers, and the protective layer is formed in an area that is enclosed with the each of the protrusions.

[Claim 11] A display apparatus comprising:

the display panel according to any one of claims 8 to 10; and

a drive unit that drives the light-emitting layers of the display panel and displays an image.

[Claim 12] A method of manufacturing a self-emitting element, wherein the self-emitting element includes a light-emitting layer that is disposed between electrodes and that emits light upon applying a voltage between the

electrodes; a protective layer that covers an emitting side of the light-emitting layer, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once at the interface in an area of the corresponding light-emitting layer; a reflective layer that covers an opposite side, as viewed from the light-emitting layer, of the protective layer; and an angle changer that is disposed at a periphery of the light-emitting layer, and changes direction of the light propagating in the protective layer so that the light is incident on the interface at less than a critical angle, the method comprising:

forming a bank, as the angle changer, that projects on the emitting side to separate the light-emitting layer from other light-emitting layer; and

forming the protective layer in an area that is enclosed with the bank.

[Claim 13] A method of manufacturing a self-emitting element, wherein the self-emitting element includes a light-emitting layer that is disposed between electrodes and that emits light upon applying a voltage between the electrodes; a protective layer that covers an emitting side of the light-emitting layer, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once at the interface in an area of the corresponding light-emitting layer; a reflective layer that covers an opposite side, as viewed from the light-emitting layer, of the protective layer; and an angle changer that is disposed at a periphery of the light-emitting layer, and changes direction of the light propagating in the protective layer

so that the light is incident on the interface at less than a critical angle, the method comprising:

forming a protrusion as the angle changer with an insulating material to separate the light-emitting layer from other light-emitting layer so that the protrusion is protruded from a bank that projects on the light-emitting side; and

forming the protective layer in an area that is enclosed with the protrusion.

[Detailed Description of the Invention]

[0001]

[Field of the Invention]

The present invention relates to a self-emitting element like an organic electro-luminescent element (hereinafter, "organic EL element"), and a display panel

[0002].

[Prior Art]

In recent years, self-emitting flat panel displays (hereinafter, "FPD") such as display panels including light-emitting elements (e.g., organic EL elements) or plasma display panels (hereinafter, "PDP") have been developed. Such display panels include a light-emitting layer disposed between an anode electrode and a cathode electrode. The light-emitting layer emits light when a voltage is applied between the electrodes. The light emitted from the light-emitting layer is recognized as characters or images when viewed through a transparent medium or a transparent panel that has a refractive index more than one.

[0003]

However, the light from the light-emitting layer is radiated, or in other words emitted in almost all

directions (emitted at all angles). Therefore, light that has an angle of incidence not less than a critical angle with respect to an interface between the transparent medium and an external medium undergoes total reflection at the interface and confined in the display panel. For example, in the case of the organic EL elements, only about 20 to 30 percent of total light, emitted from the organic EL elements, is emitted out of the display panel.

[0004]

One approach to increase the emitted light, i.e., to increase efficiency of the light or increase light extraction efficiency, slope portions may be provided inside the panel. Such slope portions allow light propagating at not smaller than the critical angle to undergo reflection or refraction, and therefore, the light is directed at an angle smaller than the critical angle. Particularly, Japanese Patent Application Laid-open No. 10-189251 discloses a top-emission display panel in which light is emitted from a side of a transparent panel covering a light-emitting layer formed on a base substrate. At a periphery of the light-emitting layer, a wedged reflecting member is disposed, and thereby a reflecting structure is formed. Moreover, Japanese Patent Application Laid-open No. 2001-332388 discloses a bottom-emission display panel in which light is emitted from a side of a base substrate on which a light-emitting layer is formed. In this bottom-emission display panel, a structure in which inclined surface portions are formed on an anode and a cathode which sandwich the light-emitting layer.

[0005]

[Patent Literature 1]

Japanese Patent Application Laid-open No. 10-189251

[Patent Literature 2]

Japanese Patent Application Laid-open No. 2001-332388

[0006]

[Problem to be Solved by the Invention]

However, in such structures in which angle of light emitted from the light-emitting layer is changed by the slope portions or inclined surface portions and thereby total reflection in the interface is inhibited, the display panel is susceptible to become thick. This may impose restriction on making of a very thin flat panel display. To improve the light extraction efficiency from the display panel, it is necessary to change by the slope portions the angle of light incident on the interface between the transparent panel and the external medium at not less than the critical angle. For this, it is necessary to design a structure such that this light or a major part of this light is incident without fail on the inclined surface. In other words, to reduce light incident on the interface between the light-emitting layer and the transparent panel at the critical angle, it is necessary to form high inclined surface portions. This results in thickening of the transparent panel. Therefore, to improve the light extraction efficiency, a thick transparent panel has to be used. This means that the thickness of the display panel is not reduced. On the other hand, if the transparent panel is made thin, the display panel can be made thin. However, the amount of light incident on the interface at not less than the critical angle increases. This results in deteriorating the light extraction efficiency.

[0007]

It is an object of the present invention to provide the self-emitting element, the display panel, and method of manufacturing self-emitting element that can achieve two conflicting requirements viz. improvement in the light

extraction efficiency and making of a thin display panel. It is another object of the present invention to provide the display apparatus that is very thin and displays a bright image by using the display panel of the present invention.

[0008]

[Means for Solving Problem]

The present invention allows light emitted from a light-emitting layer to be incident on an interface at an angle which is greater than a critical angle, that is, allows the light to undergo total reflection. Thereby, the light that has undergone total reflection is reflected on a reflective layer formed on an opposite side of the interface, and multiple reflection is caused to occur. The light with the multiple reflection is guided to an angle changer disposed at a periphery of the light-emitting layer and the angle (i.e., propagating direction) of light is changed. Namely, A self-emitting element according to the present invention includes a light-emitting layer that is disposed between electrodes and that emits light upon applying a voltage between the electrodes; a protective layer that covers an emitting side of the light-emitting layer, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once at the interface in an area of the corresponding light-emitting layer; a reflective layer that covers an opposite side of the protective layer with respect to the light-emitting layer; and an angle changer that is disposed at a periphery of the light-emitting layer, and changes a direction of the light propagating in the protective layer so that the light is incident on the interface at less than a critical angle.

[0009]

In the self-emitting element according to the present invention, a thin protective layer having a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once, is employed. This thin protective layer enables to reduce the thickness of the self-emitting element as a whole. Similar is a case in a display panel that is equipped with a plurality of light-emitting layers. Thus, by utilizing the total reflection at the interface actively, it is possible to improve the light extraction efficiency and to make the display panel thin. On the other hand, the light emitted at not less than the critical angle with respect to the interface of the protective layer is subjected to multiple reflection by the interface and the reflective layer on the opposite side of the interface. Due to the multiple reflection, the light reaches the angle changer disposed at a periphery of the light-emitting layer. Here, the angle (direction) of the light is changed and the light is output to the external medium. Since it is advisable to have a thin protective layer, an inclined structure that forms the angle changer can be made thinner than a bank or a protrusion that is mentioned below. With such a structure, the light that has reached at a periphery of the light-emitting layer due to the multiple reflection is extracted with the angle (direction) changed by the angle changer without fail. Therefore, the light extraction efficiency is increased. Moreover, a high inclined surface is not required as the angle changer. This reduces time and labor required for making the inclined structure, thereby enabling to provide the display panel at a low cost

[0010]

Thus, it is possible to provide the self-emitting

element and the display panel that can satisfy the two contradictory requirements, i.e., the improvement in light extraction efficiency and the reduced thickness of the self-emitting element or the display panel. Particularly, in a self-emitting element or a display panel in which an organic electro-luminescent light-emitting layer is employed, the light extraction efficiency is said to be 20 to 30 percent at the most. Therefore, the present invention is very effective. Thus, a very thin display apparatus that includes the display panel according to the present invention and the drive unit that displays an image by driving the light-emitting layer of the display panel can be provided and it is possible to display a bright image.

[0011]

One aspect of the angle changer that changes the angle of light propagated by the protective layer and makes it smaller than the critical angle, is a reflective surface that is inclined to have a wide emitting side. Further, the angle changer may also be a refractive surface that is inclined to have a narrow emitting side. In any of the cases, the inclined structure is necessary.

[0012]

If the inclined surface that encloses the surrounding area of the light-emitting layer is high and has a constant slope, the higher the height of the inclined surface is, the longer the distance between the light-emitting layers is. This results in bigger size of the display panel that displays an image with high resolution. Consequently, a display apparatus in which this display panel is used becomes bigger. In other words, if the inclined surface (the angle changer) is low, the distance between the light-emitting layers is short. This allows to reduce the size

of a display panel and a display apparatus that displays an image with high resolution, and to make them compact.

[0013]

Moreover, in a display panel in which a flat surface area that includes the light-emitting layer and the inclined surface corresponds to one pixel, the inclined surface (the angle changer) is included in an area of the pixel with respect to an area (light-emitting surface of the light-emitting layer) of light emission per pixel. Since the area of the angle changer is reduced by the present invention, the area of the pixel can be reduced without reducing the amount of light emitted from the pixel. This means that brightness of the display panel is improved. Thus, the present invention leads to an advantage of having high brightness by reducing a pixel size and enables to display very bright images or characters.

[0014]

In the self-emitting element and the display panel, one of the two electrodes that sandwich the light-emitting layer, in other words an electrode that is on the opposite side of the emitting side, can be made to be the reflective layer. By doing so, a special reflective layer is unnecessary, and a thinner self-emitting element and a display panel can be provided.

[0015]

In the self-emitting element and the display panel according to the present invention, it is advisable to form a bank that projects on the emitting side to separate the light-emitting layers from each other and to make an inner surface of the bank as the angle changer. The self-emitting element and the display panel according to the present invention may be constructed so that a sheet or a panel that includes the angle changer is stuck as the

protective layer. However, in this construction, light (cross talk) tends to leak through a gap between the light-emitting layer and the protective layer. Moreover, bubbles enter the gap easily during sticking the protective layer. The bubbles may cause scattering of light thereby hindering the light efficiency. Further, it may be difficult to manufacture it without cross talk or entry of bubbles.

[0016]

For this reason, the protective layer is formed in a region surrounded with the bank by making the inner surface of the bank that is formed at a periphery of the light-emitting layer as the angle changer. This allows the protective layer to be disposed very close to the light-emitting layer. In other words, it is possible to reduce the distance between the protective layer and the light-emitting layer. As a result, the cross talk is reduced. Moreover, forming the protective layer in the region surrounded with the bank may be achieved by cast coating of material of the protective layer. This cast coating enables to avoid the entry of bubbles during the formation of the protective layer. With this structure, thickness of the protective layer is absorbed in the thickness of the bank. In other words, the thickness of the protective layer does not affect the thickness of the self-emitting element or the display panel, and a thinner self-emitting element and display panel can be provided.

[0017]

Therefore, it is possible to manufacture the self-emitting element with high light efficiency by a method of manufacturing a self-emitting element, wherein the self-emitting element includes a light-emitting layer that is disposed between electrodes and that emits light upon applying a voltage between the electrodes; a protective

layer that covers an emitting side of the light-emitting layer, forms an interface between the protective layer and an external medium, and has a thickness that allows the light emitted from the light-emitting layer to undergo total reflection at least once at the interface in an area of the corresponding light-emitting layer; a reflective layer that covers an opposite side of the protective layer with respect to the light-emitting layer; and an angle changer that is disposed at a periphery of the light-emitting layer, and changes direction of the light propagating in the protective layer so that the light is incident on the interface at less than a critical angle, and the method includes forming a bank, as the angle changer, that projects on the emitting side to separate the light-emitting layer from other light-emitting layer; and forming the protective layer in an area that is enclosed with the bank.

[0018]

Furthermore, a protrusion made of an insulating material is formed so as to project toward the emitting side from the bank, and an inner surface of the protrusion may be made as the angle changer. The protective layer is formed in a region surrounded with the protrusion. However, compared to the structure in which the inner surface of the bank is made to be the angle changer, there is a possibility of occurrence of cross talk in the bank. Therefore, the structure in which the inner surface of the bank is made to be the angle changer is the most desirable. On the other hand, in the structure in which the inner surface of the bank is made to be the angle changer, when a film like that of aluminum etc. is applied on the inner side of the bank to make the angle changer, the electrodes that are disposed so as to sandwich the light-emitting

layer may get short circuited by the angle changer. Therefore, it is necessary to deposit an insulating film to avoid the short circuit. Thus, the structure in which a protrusion is formed on the bank and the inner surface of the protrusion is made to be the angle changer is suitable in view of the ease of manufacturing the display panel.

[0019]

A self-emitting element in which an insulating protrusion is formed on the bank and this protrusion is made to be the angle changer, can be manufactured by a method that includes forming a protrusion as the angle changer with an insulating material to separate the light-emitting layer from other light-emitting layer so that the protrusion is protruded from a bank that projects on the light-emitting side; and forming the protective layer in an area that is enclosed with the protrusion.

[0020]

The present invention can be applied to a self-emitting element or a display panel. Thus, the present invention is applicable to a display object or a display panel in which the PDP, a light-emitting diode (hereinafter, "LED"), an inorganic EL element, an organic EL element, or a field emission element is used. Particularly, a display object (or a self-emitting element) or a display panel in which organic EL elements including an organic EL light-emitting layer as the light-emitting layer is used has a very low light extraction efficiency. Therefore, the present invention is very useful.

[0021]

[Embodiments of the Invention]

The present invention is explained in detail below with reference to the accompanying drawings. Fig. 1 is a diagram of a portable telephone as a display apparatus in

which a display panel according to the present invention is installed. A portable telephone 1 in this embodiment includes a display panel 10a on which data is displayed and a drive unit 9. The display panel 10a includes organic EL elements which is self-emitting elements. The drive unit 9 that includes a micro computer causes the organic EL element to emit light L and a user 90 views data that includes characters and images.

[0022]

Fig. 2 is a top view of the display panel in an enlarged form. Fig. 3 is a cross sectional view of a striped area III. The display panel 10a in this embodiment is formed by disposing a plurality of pixels from the organic EL elements in a matrix form and can be driven by an active matrix or by a passive matrix. The display panel 10a includes a plurality of display objects 19 or a self-emitting element 19 that is disposed in a two dimensional direction in an array form or a matrix form. The display object 19 or a self-emitting element 19 forms one pixel and includes a separate light-emitting layer 14 and a reflective surface 13a at a periphery of the light-emitting layer 14. Therefore, a two dimensional image can be displayed by driving each of the display objects 19. Each of the display objects 19 is disposed between electrodes and includes the light-emitting layer 14 and a protective layer 18. The light-emitting layer 14 emits light when a voltage is applied between the electrodes. The protective layer 18 covers an emitting side of the light-emitting layer 14 and forms an interface 18a with an external medium. The reflective surface 13a that is an angle changer provided at a periphery of the light-emitting layer, changes the direction of light L2 that is propagated in the protective layer 18 to an angle less than a critical angle

of the interface 18a of the protective layer. Thus, the efficiency of light and light extraction efficiency are improved by changing the angle.

[0023]

The display panel 10a further includes a substrate 11 that is a support of a panel like a glass substrate. A cathode layer 12 (also called as an electrode layer 12 or a reflective layer 12) is deposited on an upper surface or a surface 11a of the substrate 11. The cathode layer 12 includes a signal line, a driving element, and a film of multiple layers of a dielectric substance or a metal like aluminum. Thus, in the display panel 10a in this embodiment, the cathode layer 12 is a reflective layer and has a function to reflect a part of light emitted from the light-emitting layer 14 toward the protective layer 18 and to reflect light that undergoes total reflection at the interface 18a toward the protective layer 18. Further, a bank 13 of a predetermined height made of polyimide is deposited in a predetermined pattern on the upper surface 11a of the substrate 11. An area 21 surrounded with banks 13 from four sides is formed. The area 21 is an area of forming the organic EL light-emitting layer 14 and is a light-emitting area. In this embodiment, the light-emitting area 21 that is rectangular in shape having a size of 60μm×190μm is formed. An area 22 (hereinafter "pixel area"), which includes inclined side surfaces (inclined surfaces) of the light-emitting area 21 and the bank 13, corresponds to a pixel in the display panel 10a and for example is a pixel area of a size 80μm×240μm.

[0024]

The light-emitting layer 14 is deposited on the area 21 using ink-jet technology. The bank 13 is a layer that can be used for alignment during depositing the light-

emitting layer 14 and separates the light-emitting layer 14. The light-emitting layer 14 may be a separate layer that includes an organic EL element or it can be a layer to which a hole transport layer or an electron transport layer is added. A transparent electrode (an anode layer) 15 made of indium tin oxide (hereinafter, "ITO") is formed on the light-emitting layer 14. When a voltage is applied to the cathode layer 12 and the anode layer 15, the light-emitting layer 14 disposed between these electrodes emits light. The protective layer 18 is deposited on the anode layer 15 (light-emitting side) and the emitting side of the light-emitting layer 14 is covered by the protective layer 18. The interface 18a is formed between the protective layer 18 and the external medium. In this case, the electrode layer 12 is a cathode and the electrode layer 15 is an anode. However, if the electrode layer 12 is a reflecting electrode and if the electrode layer 15 is an optically transparent layer, there is no need to restrict to the above mentioned combination.

[0025]

The protective layer 18 is a thin and transparent layer. The protective layer 18 has a thickness that allows the light emitted from the light-emitting layer 14 at an angle greater than the critical angle with respect to the interface 18a to undergo total reflection at the interface 18a inside the area of the light-emitting layer 14. In a conventional display panel that changes an angle at the inclined surface, a protective layer has a thickness that does not allow the light emitted from the light-emitting layer at an angle such that it undergoes total reflection, to reach an interface between the protective layer and the external medium. Whereas, in the display panel 10a in this embodiment, the protective layer 18, which has a thickness

that allows the light emitted at not less than the critical angle to be reflected at the interface 18a, is deposited thinly. Therefore, out of the light L emitted from the light-emitting layer 14, light L1 emitted at an angle smaller than the critical angle with respect to the interface 18a is output from the interface 18a to the external medium. Out of the light L, the light L2 emitted at an angle not smaller than the critical angle with respect to the interface 18a undergoes total reflection and returns toward the light-emitting layer 14 and is reflected once again at the electrode layer 12. The light L2 is propagated inside the protective layer 18. For example, if the protective layer 18 has a refractive index of 1.5, the light L2 incident on the interface 18a at not less than about 42 degrees undergoes total reflection at the interface 18a and is propagated inside the protective layer 18.

[0026]

The light L2 propagated in the protective layer 18 reaches the inclined surface of the bank 13 at a periphery of the light-emitting area 21. The angle of the light L2 is changed to less than the critical angle. Due to this, the light L2 passes through the interface 18a and is output to the external medium. In other words, a side surface 13a (hereinafter, "reflective surface 13a") of the bank 13 is inclined so that it becomes wider in the direction of the light-emitting side. A reflecting film 24 of aluminum etc. is deposited on the side surface 13a. Due to this, direction (angle) of the light L2 subjected to repetitive reflection between the interface 18a and the reflective layer 12 is changed at the reflective surface 13a. Therefore, the light L2 reflected from the reflective surface 13a is incident on the interface 18a at smaller

than the critical angle and is output. For this reason, in the display panel 10a in this embodiment, the light L2 that undergoes total reflection at the interface 18a due to the use of the thin protective layer exists. However, since the light L2 reaches the reflective surface 13a due to multiple reflection and is output to the external medium after having changed the direction, there is hardly any light that is confined due to total reflection. This enables to provide a display panel that has efficiency of light and light extraction efficiency similar to or better than those of the conventional display panel equipped with a thick protective layer and a high reflective surface.

[0027]

In the conventional display panel, the protective layer is formed so that a ray of light emitted from the light-emitting layer to the interface between the protective layer and the external medium is not reflected totally at the interface. Therefore, it is necessary to make the protective layer thicker. The thickness varies depending on the light-emitting area or the pixel area but the thickness of the protective layer becomes same or greater than the pixel size. For example, if the light-emitting area or the pixel area is 50μm×50μm, the required thickness of the protective layer 18 is 70μm. For the display panel 10a in this embodiment, since it is assumed that the light is reflected totally at the interface 18a of the protective layer 18 and the external medium, the protective layer 18 can be made thinner to the limit of performing the function of protection. Therefore, for the light-emitting area or the pixel area measuring 50μm×50μm, it is possible to manufacture a display panel having the very thin protective layer 18 of a few micro meters. This

enables to reduce the thickness of the protective layer to one tenth, thereby realizing a very thin display panel.

[0028]

Moreover, the reflective surface 13a at a periphery of the light-emitting layer 14 is for changing the direction of light subjected to multiple reflection between the protective layer 18 and the reflective layer 12. The reflective surface 13 does not change the direction of the light such that the light emitted from light-emitting layer 14 by reflecting once is not reflected totally at the interface 18a. Therefore, the height at which the light emitted from the light-emitting layer 14 at an angle such that it undergoes total reflection, is not necessary as in the conventional display panel. This enables to reduce area per pixel. Fig. 4 is an illustration indicating a relationship between the area occupied by the reflective surface 13a and the light-emitting area 21 in the pixel area 22. If the angle of the reflective surface of the display panel 10a is made same as that of the reflective surface of the conventional display panel, the height can be reduced. This enables narrowing of the area that is required to form the reflective surface 13a. Therefore, it is possible to form the light-emitting area 21 that emits same amount of light as in the conventional art with respect to the pixel area 22 and the brightness per pixel increases. Moreover, since the light propagated through the protective layer 18 is output from the surrounding of the pixel, the display object 19 has an amount of light in the surrounding equivalent to the light at the center or more. This enables a display having a high contrast and clear outline.

[0029]

To put it the other way round, in the conventional art,

since the pitch between two pixels is limited, the height of the reflective surface is limited. Therefore, the amount of light output from the interface after having changed the angle by the reflective surface is limited. Whereas, in the present invention, since the protective layer can be made thin and the height of the reflective surface (inclined surface) 24 can also be reduced, it is possible to make an inclined surface of the same height as that of the protective layer 18 or the height greater than that of the protective layer 18. This prevents escaping of light that is propagated in the protective layer 18 and enables to output the light from the interface 18a after having changed its direction. Due to this, it is possible to provide the thin display panel 10a having high light extraction efficiency. However, when the protective layer 18 is made thin, the number of reflections in multiple reflection increases. The reflection at the interface 18a is total reflection and there is not much loss. However, the light is absorbed at metal surfaces like aluminum of the electrode 12 and also during the propagation in the protective layer 18. Thus, the making of the protective layer 18 thin results in loss due to absorption and this may affect the light extraction efficiency.

[0030]

In any of the cases, in the display panel 10a in this embodiment, it is possible to make the protective layer thin without reducing the light extraction efficiency or with improvement in the light extraction efficiency. This structure enables to achieve two opposite requirements viz. improvement in the light extraction efficiency and making of a thin display panel. Thus, a bright and thin display panel can be manufactured or provided. Further, a low reflective surface can be used and not only the improvement

in light extraction efficiency but also the improvement in the brightness per pixel can be easily achieved together. Thus, it is possible to provide a display panel that can display a very bright image. Further, in the display panel 10a, since the electrode 12 disposed on a side opposite to the emitting side of the light-emitting layer 12 is also used as a reflective surface, this is the most suitable arrangement for manufacturing a thin display panel. Moreover, there is no need to consume energy more than that is required. This saves the power consumption of a display apparatus 1 and enables to improve the reliability of the organic EL element.

[0031]

Figs. 5 are diagrams indicating process in a method of manufacturing of the display panel 10a. As is shown in Fig. 5(a), a substrate 11, like a glass substrate is arranged and the electrode layer (cathode layer) 12 made of aluminum is deposited on the surface 11a. The bank 13 formed with polyimide is formed on the electrode layer 12. The reflecting film 24 which is an aluminum film or a film of multiple layers of a dielectric substance is formed on the side surface (inclined surface) 13a of the bank 13. While forming the conductive reflecting film of aluminum etc., it is necessary to form an insulating film to avoid short circuit between the electrode 12 and the electrode 15.

[0032]

Further, as is shown in Fig. 5(c), the light-emitting layer 14 is deposited on area that is surrounded with the bank 13 by impact or by dropping ink solution including an organic EL material by ink-jet method. Further, the electrode layer (anode layer) 15 is deposited on the light-emitting layer. Then, as is shown in Fig. 5(d), the thin protective layer 18 is deposited on the emitting side of

the substrate 11 formed by the electrode layer 12, the bank 13, the light-emitting layer 14, and the electrode layer 15. Thus, the display panel 10a is manufactured.

[0033]

Fig. 6 is a cross sectional view of another display panel. In the display panel 10a mentioned above, the reflective surface 13a is formed on the bank 13 that surrounds the light-emitting layer 14 and the reflective surface 13a is disposed on side of the light-emitting layer 14. In other words, there is no gap between the reflective surface 13a and the light-emitting layer 14 in a vertical direction or in a direction of emission. Thus, this structure prevents the leakage of light (cross talk) emitted from the light-emitting layer 14 and the maximum efficiency of light is achieved. Further, in this structure, the protective layer 18 is deposited to a small extent on the bank 13 but it is desirable that the protective layer 18 is on the anode layer 15. It is possible to form a structure in which the anode layer 15 is covered by the protective layer 18 having a thickness less than the height of the bank 13. This enables to have a very thin display panel. However, in this display panel 10a, to prevent short circuit between the electrodes, there is a need to form an insulating layer while forming the reflective layer 13a which may complicate the manufacturing of the display panel to a small extent.

[0034]

Whereas, in a display panel 10b that is shown in Fig. 6, the reflecting film 24 is not formed on the inclined surface 13a of the bank 13 but the anode 15 is formed on the bank 13 and the light-emitting layer 14. Further, the protrusion 25 made of an insulating material is formed on the anode 15 in a position piled up on the bank 13. The

reflecting film 24 is formed on an inclined surface 25a of the protrusion 25. The area surrounded with the protrusion 25 is covered by the protective layer 18. With this display panel 10b, there is no concern of short circuit of electrodes by the reflecting film 24 and there is no need to form an insulation film to prevent short circuit between the electrodes. This facilitates manufacturing of the display panel 10b. However, since there is a gap between the light-emitting layer 14 and the reflective surface 25a in the direction of emission, there may be a leakage of light from a part of the bank 13. The height of the protrusion 25 in the display panel 10b can be kept about the same as that of the bank or may be varied. To make the control panel thin, it is desirable that the height of the protrusion 25 is low. On the other hand, when the protective layer 18 is required to be thick enough to perform the function of protection, the thickness of the protective layer 18 can be controlled freely by adjusting the height of the protrusion 25.

[0035]

The display panel 10b can be manufactured by the following method. To start with, similarly as in the case of the display panel 10a, the electrode 12, the bank 13, and the light-emitting layer 14 are formed on the surface 11a of the substrate 11 shown in Fig. 7(a). As is shown in Fig. 7(c), the electrode layer 15 is formed on the light-emitting layer 14 and the bank 13. Further, a protrusion 25 made of an insulating material is formed on the bank 13 (i.e., piling up on the bank 13). The reflecting film 24 is formed on the inclined surface 25a of the protrusion 25. Then, as is shown in Fig. 7(d), the protective layer 18 is formed by casting a material that forms the protective layer in the area surrounded with the protrusion 25. Thus,

the display panel 10b is manufactured.

[0036]

Fig. 8 is a cross sectional view of still another display panel 10c. The display panel 10c includes the bank 13, a transparent layer 30, and a refractive surface 31. The transparent layer is piled up on the bank 13 and has a refractive index different than that of the protective layer 18. The refractive surface 31 is formed as the angle changer so that the direction of emission becomes narrow. Thus, the angle changer can also realize the refractive surface apart from the reflective surface.

[0037]

Fig. 9 is a cross sectional view of still another display panel 10d. The display panel 10d includes a protective sheet 18 that has a protrusion 28. The reflecting film 24 is formed on a wall surface (inclined surface) of the protrusion 28. The protective sheet 18 is joined to the emitting side of the substrate 11 where the bank 13 is formed, through an adhesive layer 26. In the case of this structure, if the distance between the apex of the mirror 24 and the interface 18a of the protective layer 18 is long, there is a leakage of light from the gap in between. Therefore it is desirable to prevent the leakage of light by shortening these distances (gaps) to the possible extent.

[0038]

In all the embodiments mentioned above, the reflective surface is inclined such that it is becoming wider toward the light-emitting side. It is also possible to have the reflective surface inclined so that it is becoming narrow toward the light-emitting side. However, if the reflective surface is becoming wider toward the light-emitting side, the number of reflections between the interface 18a and the

reflective layer 12 can be decreased. Therefore, considering the absorption loss at the reflective layer 12 or transmittance of the light-emitting layer 14 etc., from point of view of minimizing the decline in the optical power due to the multiple reflection, it is desirable to have the reflective surface that becomes wider in the direction of emission.

[0039]

The display panel according to the present invention is explained with an example of the display panel that is used in a portable telephone. However, the present invention can also be applied to a small sized display panel that is used in personal digital assistants (PDA), car navigation etc. The present invention can also be applied to a display for a personal computer, a television, a car navigation system, a big sized display panel of 30 inches that are being developed a lot in recent years. Moreover the light-emitting layer that uses an organic EL element is explained here. However, the present invention can also be applicable to a PDP, an LED, an inorganic EL element, and organic EL element, a field emission element etc. that use a display panel in which a light-emitting layer that emits light when the voltage is applied between the electrodes.

[0040]

[Effect of the Invention]

Thus, in the present invention, by utilizing the total reflection at the interface actively, the angle of the light that is fully reflected is changed by the angle changer like the reflective surface that is provided at a periphery of the light-emitting layer. Thus, by employing the thin protective layer the light extraction efficiency can be improved similarly as in the conventional display

panel that includes a reflecting inclined surface. This enables to manufacture the bright and very thin self-emitting element and the display panel. Moreover, the present invention enables to change the angle of propagation of light at a low (height) reflective surface thereby improving not only the light extraction efficiency but also the brightness of each pixel by reducing the size of a pixel. Thus, the self-emitting element and the display panel, in spite of being thin can display very bright images and characters than before.

[Brief Description of Drawings]

[Fig. 1] A diagram of a display apparatus (a portable telephone) in which a display panel according to the present invention is installed.

[Fig. 2] A top view of the display panel according to the present invention.

[Fig. 3] A cross sectional view of the display panel in Fig. 2.

[Fig. 4] A diagram indicating relationship between pixel area and light-emitting area in the display panel in Fig. 2.

[Fig. 5] Diagrams indicating process according to a method of manufacturing the display panel in Fig. 2.

[Fig. 6] A cross sectional view of another display panel.

[Fig. 7] Diagrams indicating process according to a method of manufacturing the display panel in Fig. 6.

[Fig. 8] A cross sectional view of still another display panel.

[Fig. 9] A cross sectional view of still another display panel.

[Explanations of Letters or Numerals]

1 portable telephone

10a, 10b, 10c, 10d display panel
11 substrate
12 cathode layer (reflective layer)
13 bank
14 light-emitting layer
14a reflective surface
18 protective layer
18a interface
24 reflecting film
25 protrusion

[Type of Document] Abstract

[Abstract]

[Problem to be solved] To provide the display panel 10a that is bright and thin.

[Solution] A display panel 10a includes a protective layer 18 that covers an emitting side of the light-emitting layer 14, forms an interface 18a between the protective layer 18 and an external medium, and has a thickness that allows the light emitted from the light-emitting layer 14 to undergo total reflection at least once at the interface 18a in an area of the light-emitting layer 14; a reflective layer 12 that covers an opposite side, as viewed from the light-emitting layer 14, of the protective layer 18; and a reflective surface 13a that is disposed at a periphery of the light-emitting layer, and changes a direction of the light propagating in the protective layer. In the display panel 10a, the light emitted from the light-emitting layer 14 undergoes total reflection at the interface 18a, occurs multiple reflection between the interface 18a and the reflective layer 12, and output to the external medium after changing the angle at the reflective surface 13a of a periphery of the light-emitting layer 14. Consequently, it is possible to improve the light extraction efficiency and provide the display panel 10a that is bright and thin.

[Chosen Drawing] Fig. 1

[Type of Document] Drawings

FIG.1

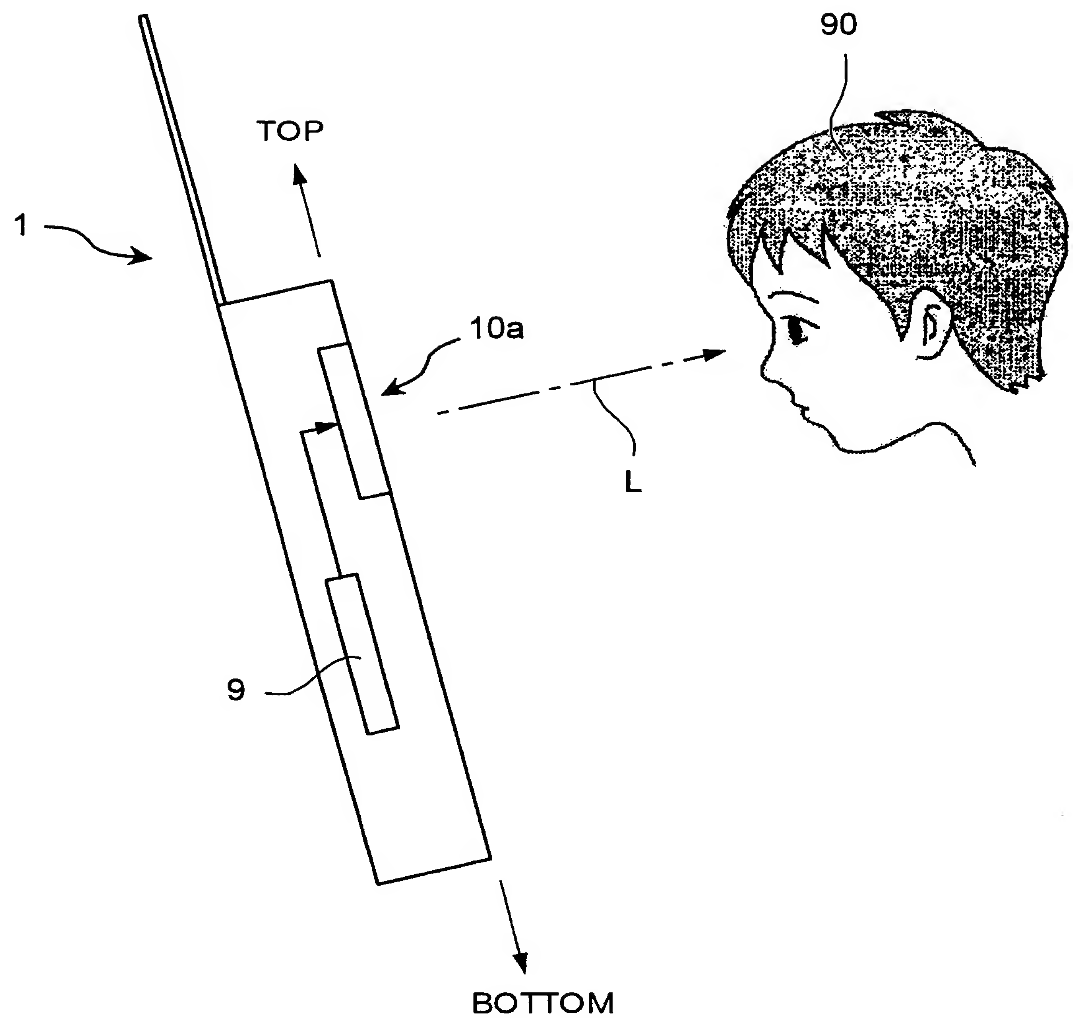


FIG.2

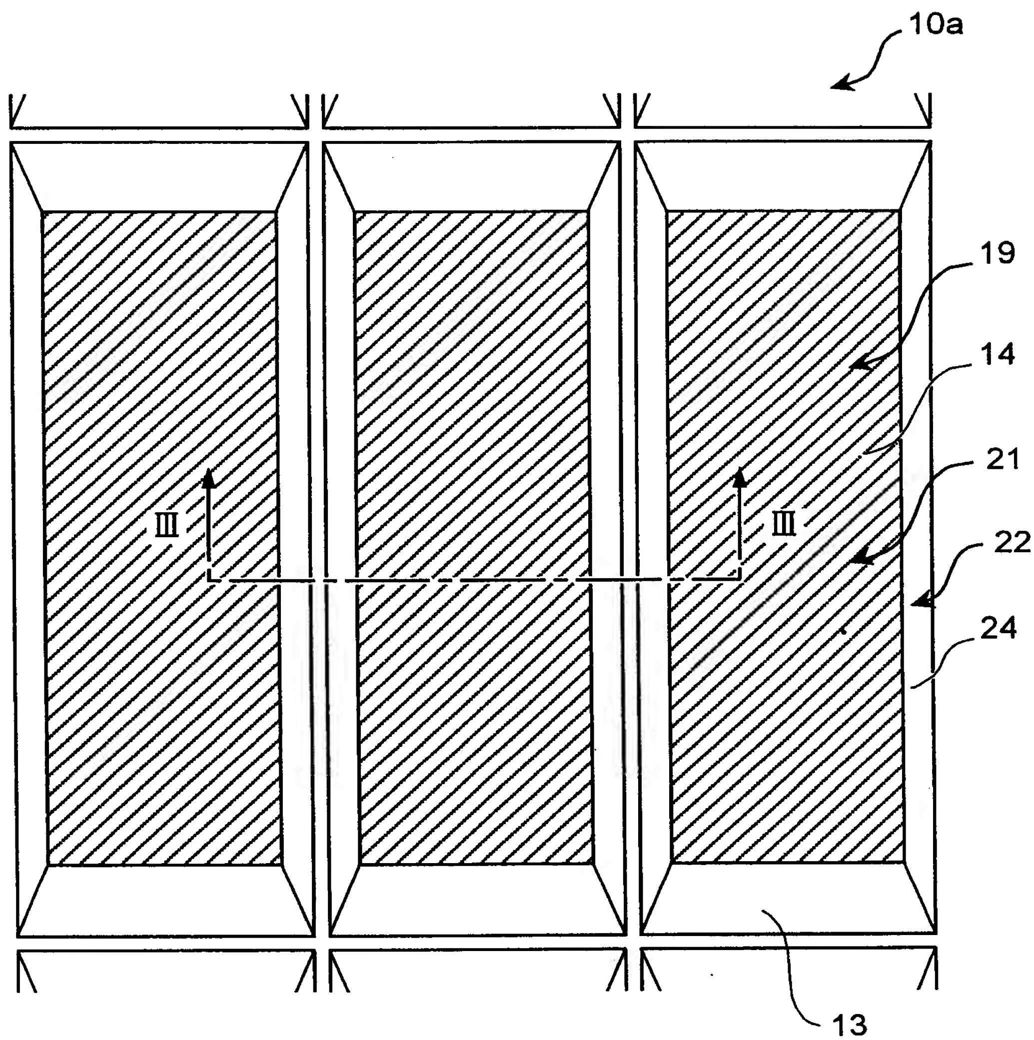


FIG.3

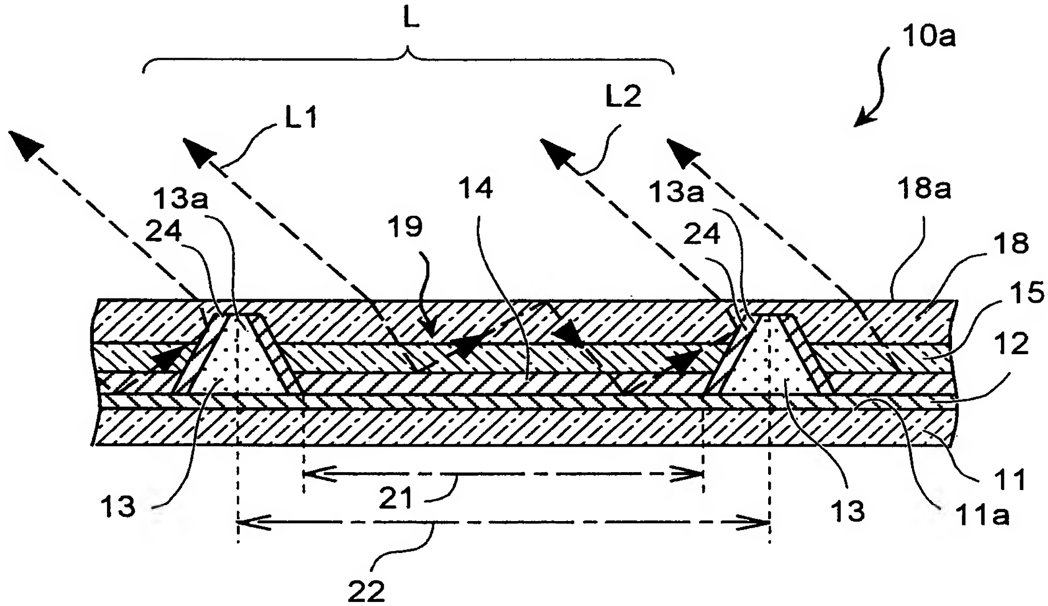

L
10a
L1
L2
13a
24
19
14
13a
24
18a
18
15
12
13
21
13
11
11a
22

FIG.4

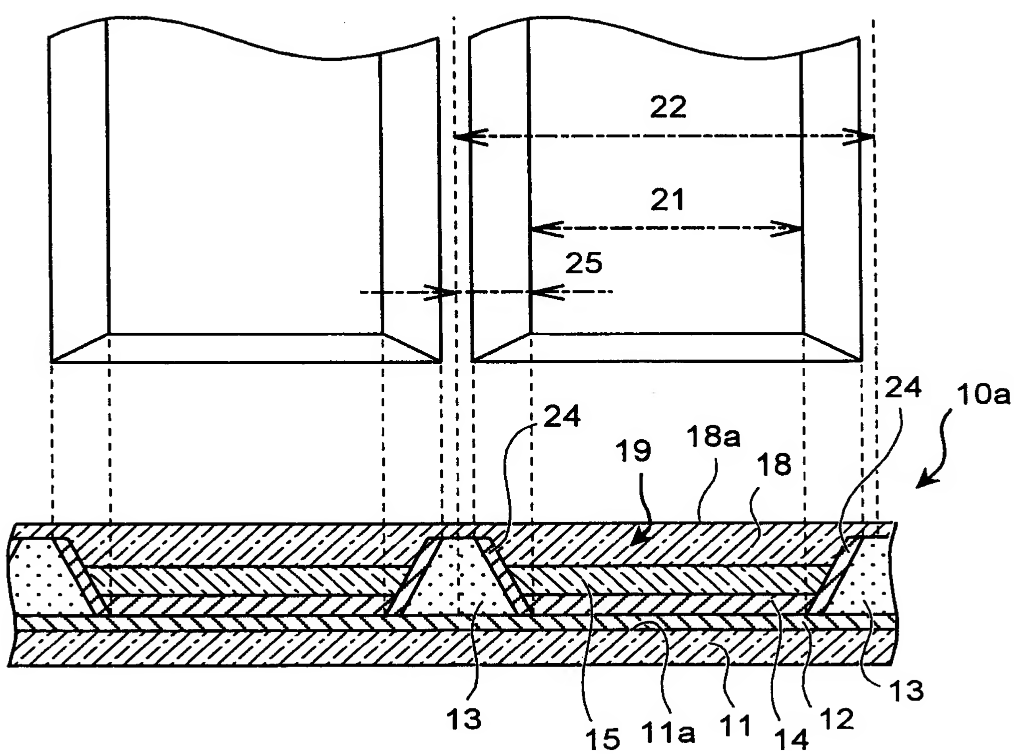
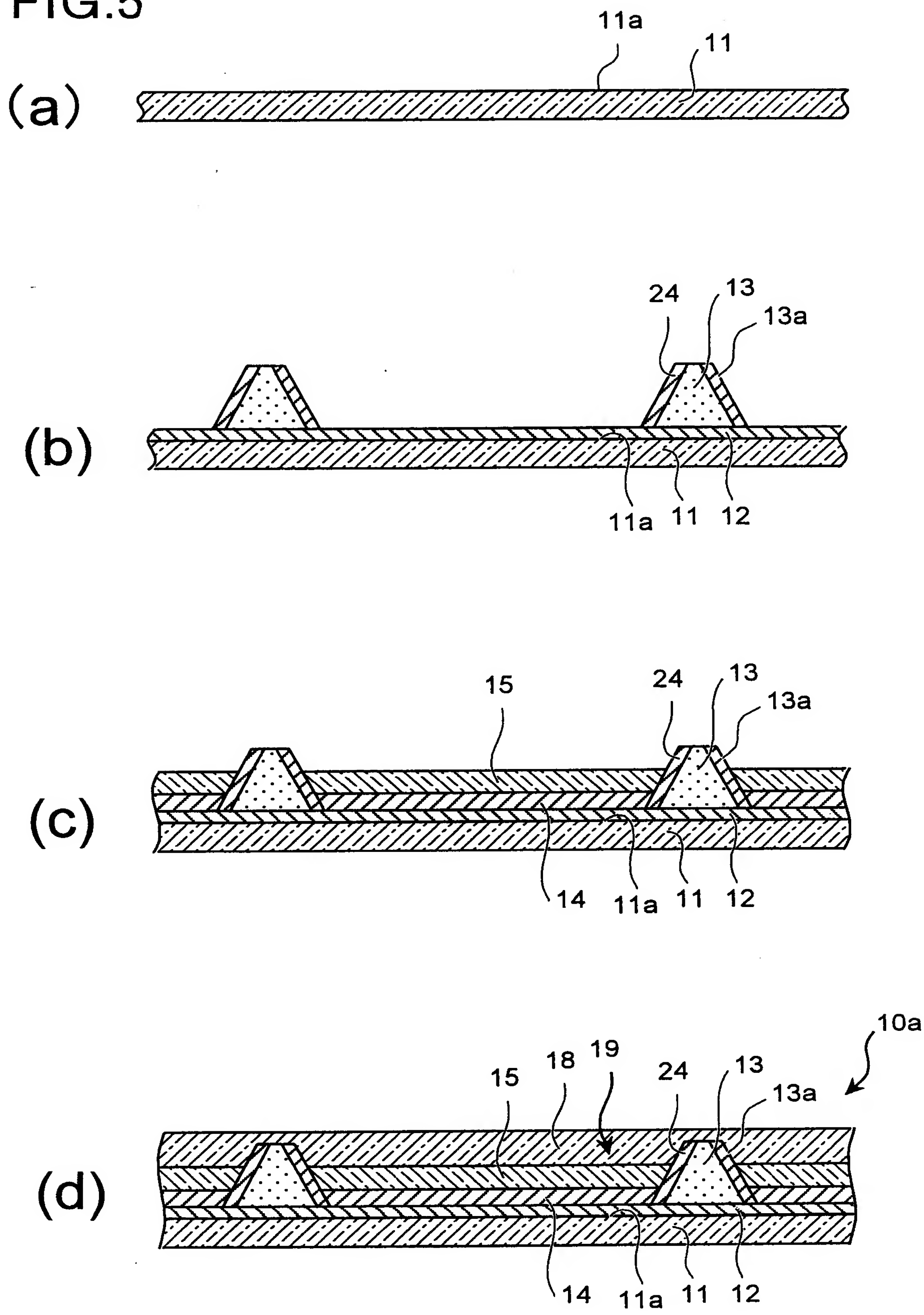

22
21
25
24
24
10a
19
18a
18
13
15
11a
11
14
12
13

FIG.5



(a)
11a
11
(b)
24
13
13a
11a
11
12
(c)
15
24
13
13a
14
11a
11
12
(d)
10a
15
18
19
24
13
13a
14
11a
11
12

FIG.6

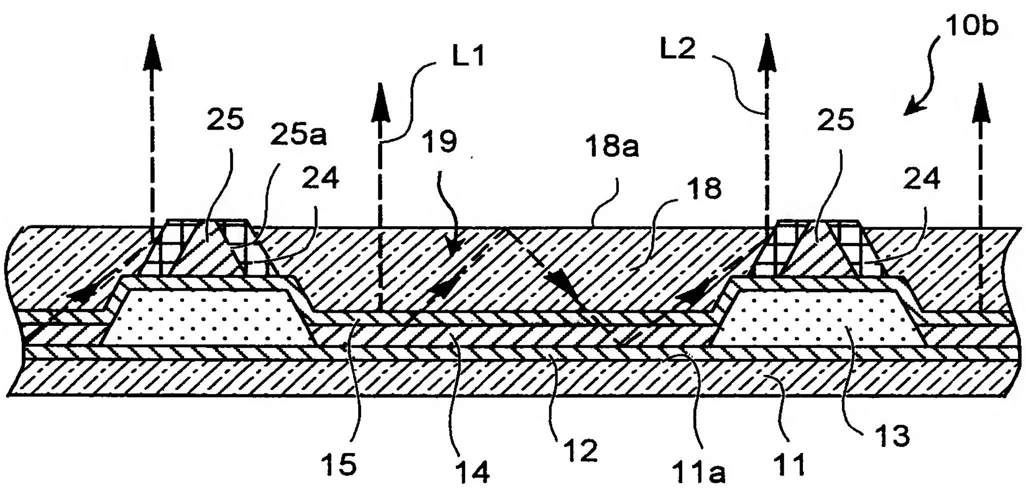
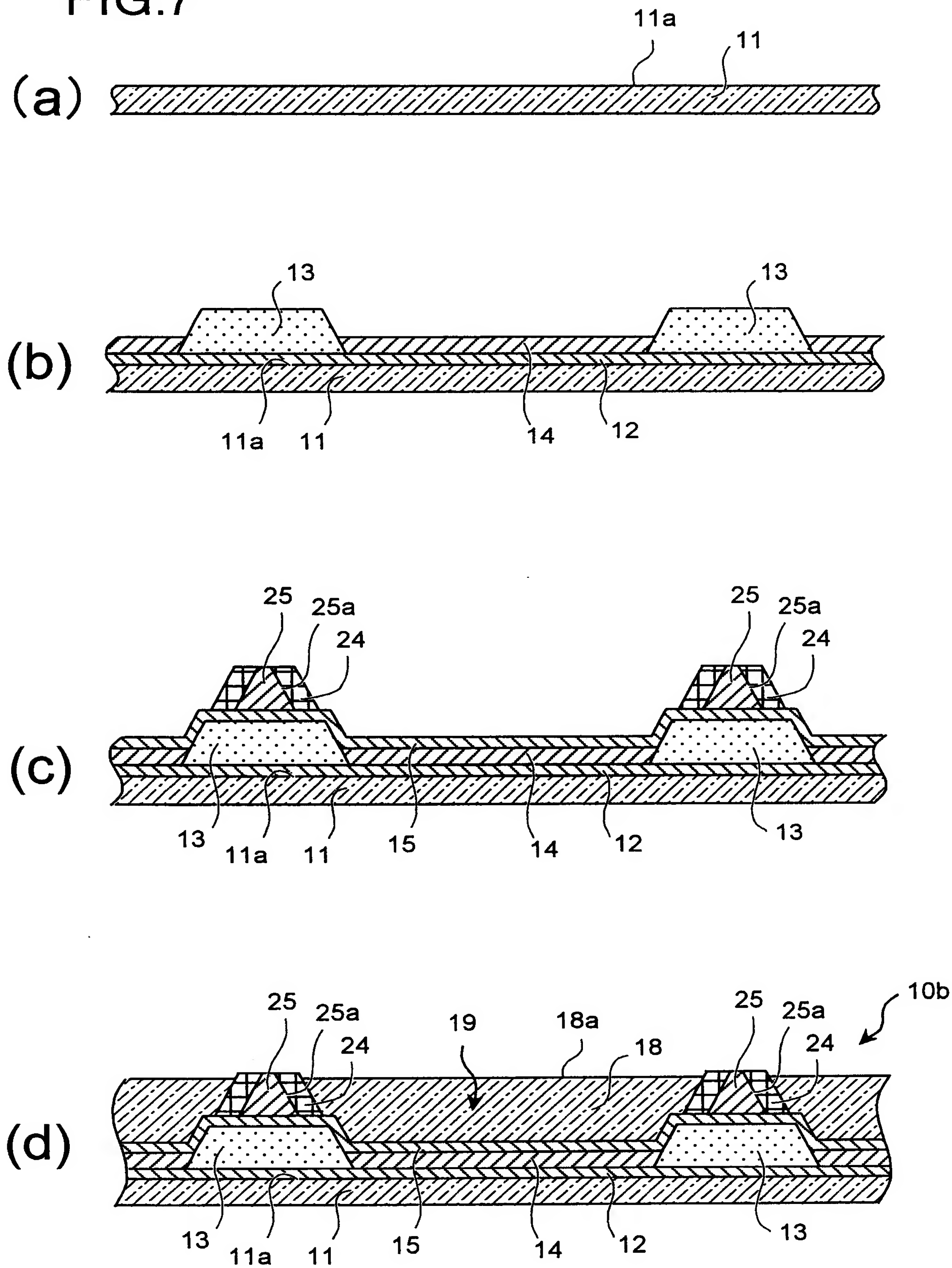


FIG.7


(a)
11a
11
(b)
13
13
11a
11
14
12
(c)
25
25a
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25a
24
13
11a
11
15
14
12
13
(d)
25
25a
24
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18a
18
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25a
24
10b
13
11a
11
15
14
12
13

FIG.8

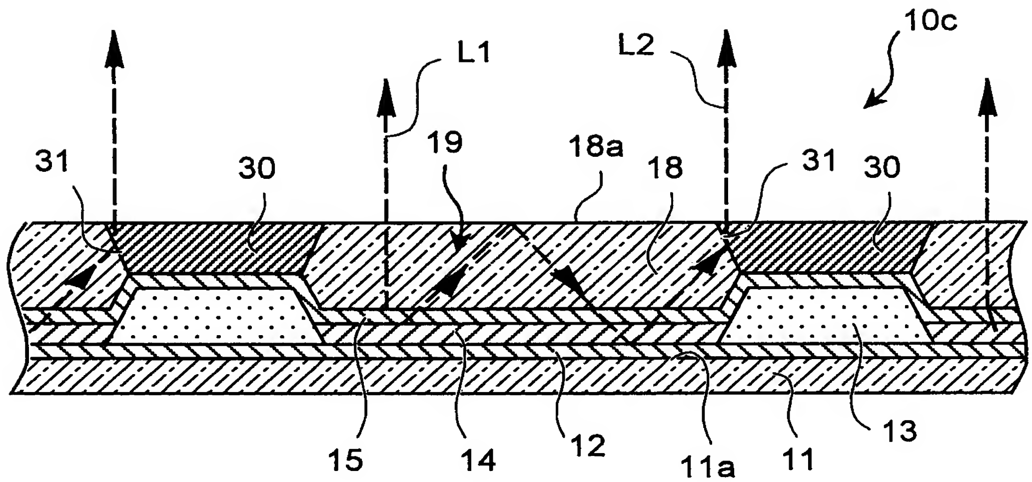
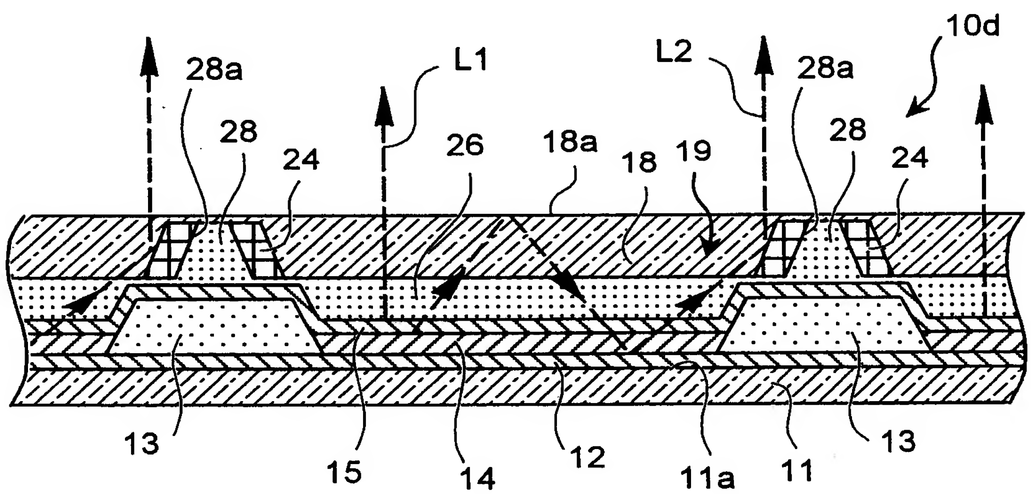

10c
L1
L2
31
30
19
18a
18
31
30
15
14
12
11a
11
13

FIG.9


10d
L1
L2
28a
28
24
26
18a
18
19
28a
28
24
13
15
14
12
11a
11
13